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**The Effects of Whole Body Vibration on Muscle Activity**

**by**

**Tom Hazell**

**A Thesis**

**Submitted to the Faculty of Graduate Studies and Research  
through Kinesiology  
in Partial Fulfillment of the Requirements for  
the Degree of Master of Human Kinetics at the  
University of Windsor**

**Windsor, Ontario, Canada**

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## ABSTRACT

The present study attempted to determine the optimal vertical vibration stimulus (frequency x amplitude) to activate upper and lower body agonist/antagonist muscle pairs during three distinctive actions: an isometric semi-squat, unloaded dynamic leg squats, and bilateral bicep curls. To determine changes in muscle activity isometric and dynamic whole body vibration (WBV) electromyography (EMG) from the vastus lateralis (VL), biceps femoris (BF), biceps brachii (BB), and triceps brachii (TB) muscles was recorded and expressed as a % of maximum voluntary exertion (MVE). WBV resulted in increases in muscle activity of 0.6-8.7%MVE in the VL, 0.3-2.0%MVE in the BF, 0-0.8%MVE in the BB, and 0.2-1.0%MVE in the TB as compared to no vibration. While an optimal WBV stimulus could not be determined, the higher WBV amplitude (4mm) and frequencies (35, 40, 45Hz) resulted in the greatest increases in muscle activity. Overall, the dynamic conditions had higher muscle activity and greater EMG increases with vibration suggesting WBV training should include dynamic activities.

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## CHAPTER I

### INTRODUCTION

#### Whole Body Vibration

Whole body vibration (WBV) has been used a new method of skeletal muscle training that reportedly results in improvements in both isometric and dynamic muscle strength and performance. While the term whole body vibration



Figure 1 - What most people think of when they first hear the term whole body vibration (<http://www.geocities.com/sgb345/exercise-belt.jpg>)

conjures up the once commercially advertised old vibrating belt attached to a motor wrapped around the waist (Figure 1), this is not the method of whole body vibration that has recently been appearing in the scientific literature. The technology and application of a vibration stimulus was developed and updated by Nazarov & Spivak (1985), who demonstrated that training with a vibration stimulus of small amplitudes could enhance muscle strength. These scientists concluded that the vibration stimulus led to increases in

muscle strength by increasing motor unit (MU) synchronization in athletes. Since their original discussion in 1985, the technology and application of whole body vibration has been advanced.

The current technology for WBV has a vibration stimulus generated via a vertically oscillating platform of two separate designs. The two commercially available WBV platforms are illustrated in Figure 2, the first (A) oscillates with reciprocating displacements on both sides of a fulcrum in a teeter totter like motion, and the other platform type (B)

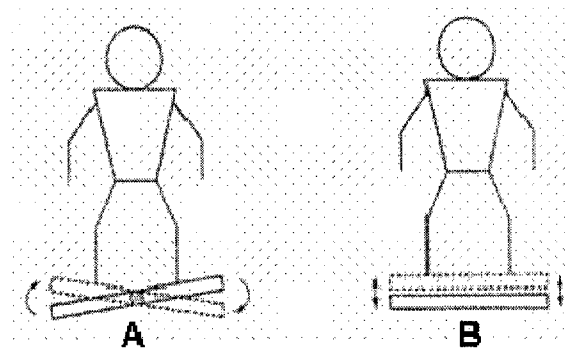


Figure 2 - Platform Types - A) oscillates with reciprocating displacements on both sides of a fulcrum; (B) strictly vertical oscillations (Cardinale & Wakeling, 2005)

oscillates uniformly up and down (Cardinale & Wakeling, 2005). The teeter totter design is employed by a WBV device known as the Galileo and its prototypes. The vertically vibrating design is used by the PowerPlate, Kuntotäry, and the WAVE (Whole Body Advanced Vibration Exercise) platforms. The WBV stimulus produced by both of these platform types is sinusoidal and is characterized by its frequency and amplitude (Griffin, 1996). The frequency of the vibration is the number of oscillations (cycles of motion) per second expressed (Hertz; Hz) with a range from 15-50 Hz used in the literature whereas the amplitude of the signal is the peak-to-peak amount of vertical displacement of the platform which is generally measured and expressed in millimetres (mm) with ranges from 1-105 mm in the literature. The frequency and amplitude of vibration determines the intensity of the stimulus placed on the neuromuscular system (Mester, Spitzenfeil, & Yue, 2002). The generation of this high frequency, low amplitude sinusoidal signal is transmitted to the body where it causes a tonic excitatory

effect on the muscles exposed to the vibration (Torvinen et al., 2002a). This response of the muscle tissue is thought by many to represent the stretch reflex mechanism, termed the 'Tonic Vibration Reflex' or TVR (Hagbarth & Eklund, 1966) as seen in Figure 3.

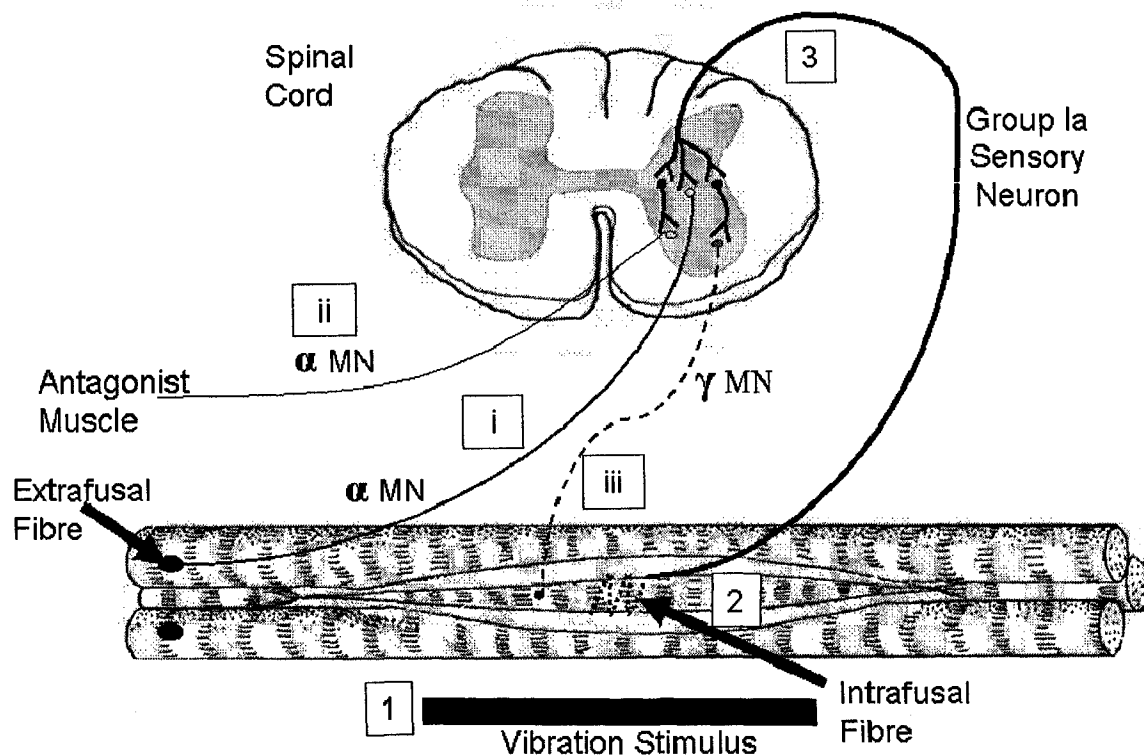


Figure 3 – Tonic Vibration Reflex - The vibration stimulus (1) causes short and rapid changes in muscle fibre length that are detected by the muscles spindles (2) which send Ia sensory neurons to the spinal cord (3). In the spinal cord these Ia sensory neurons can : (i) use a mono-synaptic projection (direct) to excite an alpha motor neuron that will stimulate a reflexive muscle contraction in the extrafusal muscle fibre of the same muscle, (ii) use a poly-synaptic projection to inhibit an alpha motor neuron preventing antagonist muscle activity, (iii) use another poly-synaptic projection to activate a gamma motor neuron that will cause the intrafusal muscle fibre of the agonist muscle to maintain its sensitivity to further vibration perturbations.

### Stretch Reflex Mechanism

The WBV stimulus causes short and rapid changes in muscle length that are detected by the primary sensory endings of intrafusal fibres located in muscle spindles (Cardinale & Bosco, 2003). The primary sensory endings are highly sensitive to any small changes in length (Mester, Spitzenfeil, Schwarzer, & Seifriz, 1999) and respond by sending afferent information about these length changes to the spinal cord via Ia sensory neurons (Matthews, 1966). In the spinal cord, these Ia sensory neurons have mono- and poly-synaptic projections. They can mono-synaptically (directly) excite alpha motor neurons ( $\alpha$  MN) that innervate the extrafusal fibre of the same muscle causing an involuntary reflexive contraction (Mester et al., 1999). This contraction acts to control the original change in muscle length caused by the vibration stimulus. The Ia sensory neuron can also poly-synaptically excite an inhibitory interneuron that prevents antagonist muscle activation and further complimenting the original reflexive contraction of the agonist muscle. The same Ia sensory neuron can also poly-synaptically excite an excitatory interneuron that activates a gamma MN ( $\gamma$  MN) which allows the intrafusal fibre of the agonist muscle to maintain its sensitivity and responsiveness to further vibration perturbations (Cardinale & Bosco, 2003). It is also thought that the vibration stimulus affects intrafusal fibre secondary endings as well as receptors in the skin and joints which also provide sensory input to a  $\gamma$  MN again affecting sensitivity and responsiveness (Mester et al., 1999). While it is still unknown if the TVR can be elicited by a low frequency, low amplitude signal produced by a WBV platform, the reflexive muscle contraction evoked by the vibration stimulus leads to many beneficial adaptations that have

been reported in the literature such as improvements in bone density, blood flow, and hormone profile (Bosco et al., 2000; Kershan-Schindl et al., 2001; Verschueren, Roelants, Delecluse, Swinnen, Vanderschueren, and Boonen, 2004).

## CHAPTER II

### REVIEW OF LITERATURE

#### Whole Body Vibration Training Studies

##### *Isometric Training and Performance*

To investigate the effects of a vibration stimulus on skeletal muscle performance, Bosco et al. (1999b) applied a 26 Hz, 10 mm [Galileo] stimulus for 60 sec with a 60 sec rest for 10 sets to a subject standing with one leg on the vibration platform in an isometric flexed position at 100° knee angle. Though the training in this study was isometric, they reported significant increases in average force (0.34%), velocity (6.25%), and power (6.75%) in dynamic leg press exercises at different loads. Using a vibrating grip apparatus set at 30 Hz with 6 mm amplitude, Bosco, Cardinale, & Tsarpela (1999a) also examined the acute effect of vibration on arm strength in a semi-flexed position for 5 sets of 60 sec with 60 sec rest. They demonstrated that this upper body isometric WBV training protocol also significantly increased power (13%) as determined by the speed of load displacement.

In contrast to Bosco and colleagues (1999b), de Ruiter, Vaan Raak, Schilperoort, Hollander, & de Haan (2003) completed an 11 week study that had subjects stand with their knees bent at a 110° angle while a 30 Hz, 8 mm signal [Galileo] was applied for 5 sets of 60 sec with 60 sec rest, 3 times per week (wk) but reported no benefit of WBV training. Similarly, Cochrane, Legg, and Hooker (2004) had subjects stand on the platform in 5 different positions (standing upright, squatting (knees bent 90°), squatting (knees bent 90°) with feet externally rotated, standing on right leg and then left leg) for two 60 sec

exposures with 40 sec rest at a vibration stimulus of 26 Hz, 11 mm [Galileo] for a total of 9 exposures but found no improvements in vertical jump, sprint time, or agility tests.

### *Combined - Isometric and Dynamic Training and Performance*

With some equivocal results on strictly isometric WBV training, research has emerged combining isometric and dynamic WBV training. Rittweger, Beller, and Felsenberg (2000) examined the effect of an acute exposure to WBV training with an external load of 40% and 35% of body weight attached to male and female subjects respectively. Subjects completed 30 sec of simple standing followed by dynamic squatting exercises until exhaustion at a frequency of 26 Hz and an amplitude of 105 mm [Galileo]. This acute WBV exposure resulted in a decrease in force (9.2%) and vertical jump height (9.1%) as well as an increase in heart rate (42.5%) and oxygen consumption (48.8%) which suggest this selected frequency and amplitude combination protocol may have resulted in fatigue.

In 2002(a), Torvinen and colleagues applied an increasing WBV stimulus (5 Hz every minute) while the subjects performed a 60 sec exercise routine consisting of 10 sec of light squatting, standing straight up, standing relaxed, light jumping, shifting body weight from leg to leg, and heel standing for 4 consecutive minutes while the vibration frequency increased from 15 Hz to 30 Hz at a constant amplitude of 10 mm [Galileo]. This single 4 minute exposure resulted in significant increases in isometric extension strength of the lower extremities



(3.2%), jump height (2.5%), and body balance (15.7%). In a second study Torvinen, Sievanen, Jarvinen, Pasanen, Kontulainen, & Kannus (2002c) used the identical protocol but with a higher 25-40 Hz signal and a reduced 2 mm amplitude [Kuntotäry]. This protocol however, resulted in no positive effects on functional performance measures such as balance, strength, or jumping ability. In a third study by Torvinen et al. (2002b) used the same protocol, but increased the number of WBV exposures to 3-5 times per week [Kuntotäry]. They reported significant increases in both isometric leg extension strength (3.7%) and vertical jump height (10.2%) with only 2 months of training. After 4 months of training vertical jump height increased even further (8.5%) but isometric leg extension strength had not increased further. After 8 months, Torvinen et al. (2003) reported the subjects still exhibited an increase in vertical jump height (7.8%) but no effect was seen on isometric leg extensor strength.

Delecluse, Roelants, and Verschueren (2003) used a 35-40 Hz stimulus with 2.5-5 mm amplitude [PowerPlate] with unloaded static and dynamic knee extensor exercises such as squats, deep squats, wide-stance squats, one-legged squats, and lunges and compared it to a traditional resistance training protocol (Kraemer et al., 2002). They reported WBV training resulted in gains in isometric (16.6%) and dynamic strength (9%) as well as in jumping ability (7.6%) whereas the traditional resistance trained group led to smaller increases in isometric (14.4%) and dynamic strength (7%) and did not lead to any changes in jumping ability. These results demonstrate that the WBV training resulted in greater gains in strength and performance than the traditional resistance training group.

Roelants, Delecluse, Goris, and Verschueren (2004a) used a similar program to Delecluse et al. (2003), but used a vibration frequency of 35-45 Hz [PowerPlate] with the same amplitude (2.5-5 mm) and also added bicep curls to the exercises performed on the platform. Their results had the WBV trained group increase their isometric knee extensor strength greater than the group that was trained with a standard resistance training program (24.4% to 16.5%), though the mean gain in isokinetic knee extensor strength was similar in both groups. No data was reported on any changes in bicep muscle strength following the vibration training.

In 2004, Verschueren, Roelants, Delecluse, Swinnen, Vanderschueren, and Boonen applied a 35-40 Hz stimulus with 1.7-2.5 mm amplitude [PowerPlate] to a group of post-menopausal women (58-74 years) using the same routine as Delecluse et al. (2003) except for 24 weeks and compared it to a standard ACSM training protocol for people over 60 (Mazzeo et al., 1998). The WBV training resulted in similar if not greater increases than the resistance trained group in isometric strength (15% to 16%) and dynamic strength (16.5% to 10.6%). Similarly, Roelants, Delecluse, and Verschueren (2004b) also had post-menopausal subjects (58-74 years) perform the same exercise routine as the previous study with the same vibration stimulus frequency but with a higher amplitude of 2.5-5 mm. Results showed that both WBV training and resistance training resulted in similar increases in isometric strength (12.4% to 16.8%), dynamic strength (12.1% to 12.5%), and jump height (16% to 12.1%).

In 2005, Cochrane and Stannard examined WBV training on young females with a vibration signal of 26 Hz, 6 mm [Galileo] using 6 positions (standing upright with knees locked, standing with knees bent to a 120°, kneeling on the ground with their hands on the platform and arms straight, simple squatting, and standing in a lunge position with the left or right leg on the platform). They reported significant improvements in vertical jump height (8.1%) and in a sit and reach flexibility test (8.2%). Interestingly, Delecluse and colleagues (2005) examined elite male and female sprint trained athletes at a vibration frequency of 35-40 Hz with 1.7-2.5 mm amplitude [PowerPlate], 3 times per week for 5 weeks plus a conventional training program and reported no increases in strength, power, or performance.

### *Dynamic Training and Performance*

There have been very few studies looking at strictly the performance effects of dynamic WBV training. Issurin, Liebermann, and Tenenbaum (1994)

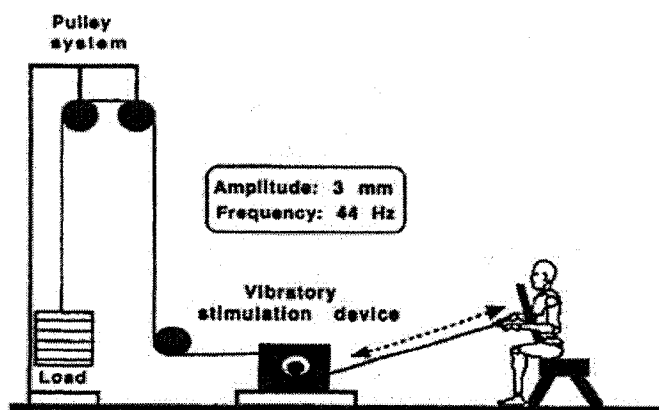


Figure 4 - The Vibrating Cable design for bicep curls (Issurin, Liebermann, & Tenenbaum, 1994).

compared vibration training to standard weight training 3 times per week for 3 weeks. The vibration stimulus was a 44 Hz, 3 mm signal that was applied to a cable attached to a weight stack (Figure 4). They reported vibration training

resulted in a 49.8% increase in 1 Repetition Maximum (1-RM) whereas the conventional strength trained group only increased 16.1%. Additionally, Issurin and Tenenbaum (1999) examined the acute effect of training with the same vibrating cable (Figure 4) while performing bilateral barbell curls at 44 Hz, 3 mm. Subjects in this study were male amateur and professional power trainers who performed 2-3 sets of contractions as fast as possible with a load of 65-76% of their 1-RM. This routine led to increases in maximum power and mean power (10.4% and 7.9%) and mean power (10.2% and 10.7%) in both the professional and amateur groups respectively.

Another study by, Rittweger, Mutschelknauss, and Felsenberg (2003) examined the effects of dynamic squatting with an additional load of 40% of body weight until exhaustion with a vibration stimulus of 26 Hz, 12 mm amplitude [Galileo]. This study resulted in the WBV group having a faster time to fatigue compared to the no vibration group (349 sec to 515 sec). Rittweger and colleagues speculated that this faster time to fatigue demonstrated an increase in muscle activity during squatting. Similarly, Rønnestad (2004) examined the effect of WBV during a loaded traditional squat. He compared squats with a vibration stimulus of 40 Hz to squats without a vibration stimulus for 5 weeks of training, 2-3 times per week (13 total sessions) with 3-4 sets of 6-10 repetitions. He reported the WBV trained group significantly increased their 1-RM (32.4%) and vertical jump height (9.1%) where the non-WBV trained group significantly increased 24.2% in their 1-RM and non-significantly increased their vertical jump height by 4.2%. The results demonstrate the WBV trained group had a

significant increase in vertical jump height over the non-WBV trained group and a trend towards a significant increase in 1-RM.

Another dynamic training study by Mester, Kleinöder, and Yue (2005) compared WBV training with a 30-50 Hz signal and two different amplitudes of 2 and 4 mm [PowerPlate] to traditional resistance training. They reported that the WBV training with 2 mm and 4 mm resulted in the greatest increases in both isometric (5 and 10%) and dynamic strength (15.3 and 22.2%) as well as in the performance measures of squat jump (14.3 and 17.9%), drop jump (13.3 and 15.6%), and countermovement jump (17.9 and 11.9%). Within the WBV training, the 4 mm amplitude was the most optimal in increasing strength but both WBV training groups improved more than the traditional resistance training group. In 2006, Kvorning et al. completed a 9 week study similar to Rønnestad (2004) but compared loaded squat training to loaded squat training with vibration and to unloaded squat training with vibration. The vibration stimulus was 20-25 Hz, 4mm [Galileo] and both loaded conditions completed 6 sets of 8 repetitions with a load of 8-10-RM. This study demonstrated loaded squat training with vibration did not result in any greater increases than traditional loaded squat training

To date there is little or no evidence to substantiate the acceptance of selected WBV training protocols as most studies use different frequencies, amplitudes, and/or durations of a vibration stimulus to elicit an effect. However, the evidence seems to suggest that vibration training may allow greater gains in muscular performance than traditional resistance training (Delecluse et al., 2003; Mester et al., 2005; Rønnestad, 2004). Furthermore, WBV training has

incorporated both isometric and dynamic contractions as well as a combination of both to evoke measurable changes. In the greater picture of WBV training there is very limited data on which WBV frequency to use and which amplitude is best in WBV training.

### Whole Body Vibration and Muscle Activity

To indirectly examine the ability of WBV to stimulate muscle activity, electromyography (EMG) is a useful tool as it allows analysis of a muscle's response to the vibration signal (Griffin, 1996). Using a variable of EMG termed EMGrms (root mean square) allows a measure of muscle activity or myoelectric activity (Chaffin, 1999). Bosco et al. (1999a) reported that a WBV signal of 30 Hz, 6 mm via vibrating dumbbells [Galileo] for 5 sets of 60 sec with 60 sec rest during an isometric semi-flexed bicep curl resulted in a 225% increase in EMGrms.

Similarly, Cardinale and Lim (2003) examined an isometric half squat (knee angle 100°) and measured the EMG activity in the vastus lateralis muscle reporting a 34% increase in EMGrms to a 30 Hz, 10 mm signal [Galileo]. Rittweger et al. (2003) examined the effect of a 26 Hz, 6 mm stimulus [Galileo] on dynamic loaded squatting (40% body weight) to exhaustion and reported a faster time to fatigue as well as a decrease in EMG median frequency in the vastus lateralis muscle. Median frequency is an index of fatigue whereby frequencies of a muscle activity spectrum shifts towards lower frequencies and

has been observed for isometric and dynamic contractions. This faster time to fatigue led the researchers to suggest that WBV caused greater muscle activity.

A group of researchers in Finland have also used EMG to look at muscle activity with WBV. Torvinen et al. (2002a) used a vibration stimuli of 15-40 Hz, with 10 mm amplitude [Galileo] for a continuous 4 minute exposure while subjects completed unloaded isometric and dynamic exercises. The results of this study demonstrate the vibration stimulus caused a significant decrease in the mean power frequency of EMG in the soleus and vastus lateralis, as well as a significant increase in EMGrms in the soleus and gastrocnemius in the 4th minute of exposure compared to the 1st minute. Mean power frequency is similar to median power frequency as it is a marker of muscle fatigue when the mean of the frequencies in EMG shifts to lesser frequencies. Torvinen et al. (2002c) also used the same protocol but with only 2 mm amplitude [Kuntotäry] and reported no significant changes in EMG in either muscle (soleus and vastus lateralis), but did report an increase in the gluteus medius.

A recent study by Roelants, Verschueren, Delecluse, Levin, and Stijnen (2006) examined the effect of a 35 Hz, 2.5 mm [PowerPlate] vibration stimulus on 3 isometric positions (high squat, low squat, and one-legged squat). The knee angle during the high squat and one-legged squat was 125° and 90° during the low squat where muscle activity was measured from the rectus femoris, vastus medialis, vastus lateralis, and gastrocnemius muscles. The results of this study demonstrated that WBV led to significant increases in EMGrms in all muscles during all positions. During the high squat, WBV resulted in increases between

92.5-301% when compared to the control condition. In the low squat position, WBV increased muscle activity in the range of 49-134% compared to control and increases of 115-360% during the one-legged squat. While being exposed to the whole-body vibration stimulus, the leg muscles measured were activated between 12.6-82.4% of their maximal activation.

Collectively, the EMG data on WBV effects on skeletal muscle are positive, though there is limited data on the efficacy of the optimal frequency and amplitude to apply. Frequency protocols have ranged from 15 Hz to 50 Hz, amplitudes have ranged from 1.7 mm to 105 mm, and training durations have ranged from as short as 20 sec to as long as 4 minutes.

#### *Frequency Effects on EMG*

In terms of frequency (Figure 5), Cardinale and Lim (2003) examined the effect of 3 different vibration frequencies on muscle activity. They used a vibration stimulus with 10 mm amplitude and frequencies of 30, 40, and 50 Hz [Galileo] and collected EMG data from the vastus lateralis muscle in an isometric half squat position (knee flexed to 100°). They reported the 30 Hz frequency signal elicited the greatest muscular activity, though all 3 vibration signals increased muscle activity greater than no vibration. This is the only study to suggest an optimal vibration frequency of 30 Hz at 10 mm amplitude. A recent review by Luo, McNamara, and Moran (2005) suggested that the most effective frequencies to use in whole body vibration training are between 30-50 Hz as Mester, Spitzenpfeil, and Yue (2002) has suggested that frequencies below 20



Hz are dangerous and frequencies above 50 Hz may see a larger attenuation by muscles.

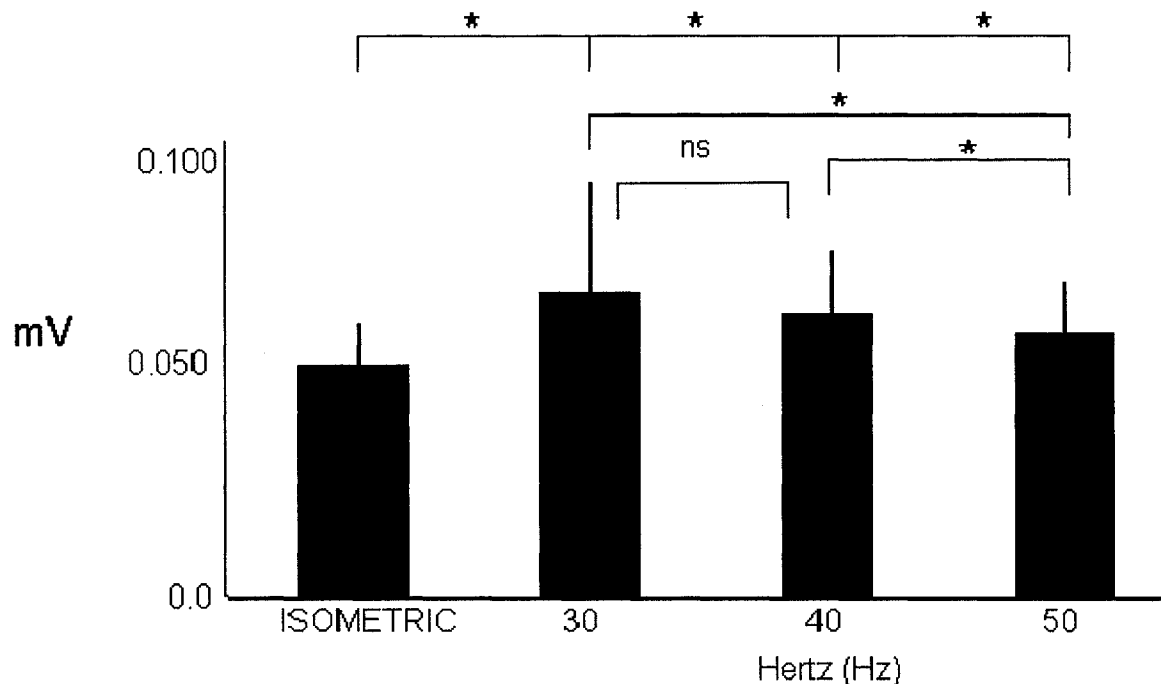


Figure 5 - Electromyography root mean square (EMGrms) values recorded from the vastus lateralis muscle during an isometric semi-squat (100° knee angle). The error bars indicate standard deviation. \* $p < 0.05$ ; ns=not significant; mV=millivolts. Adapted from Cardinale & Lim, 2003.

#### *Amplitude Effects on EMG*

In terms of amplitude, two of the studies by Torvinen et al. (2002a,c) reviewed earlier, demonstrated that higher amplitudes (10 mm) may be required to more effectively activate muscles of the lower body as a smaller amplitude of 2 mm had no effects on muscle activity. A study by Mester et al. (2005) compared WBV training with a 30-50 Hz signal and two different amplitudes: 2 mm and 4 mm [PowerPlate] to traditional resistance training (Figure 6). They reported WBV at 4 mm amplitude led to the greatest increases in isometric and

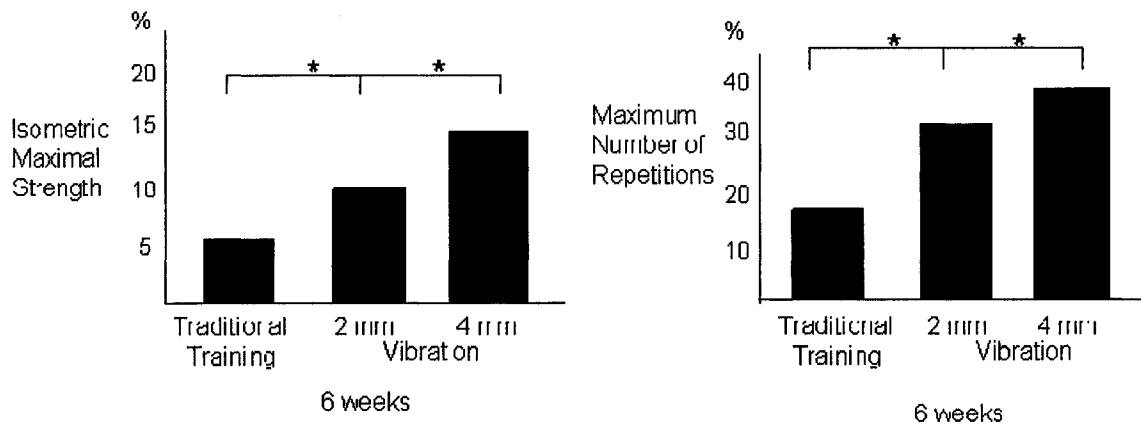


Figure 6 - Increases in strength in response to vibration training with a frequency of 30-50 Hz and amplitudes of 2 mm or 4 mm. \*  $p < 0.05$ . Adapted from Mester et al., 2005.

dynamic strength as well as in performance. Notably, the 2 mm WBV training stimulus demonstrated greater improvements than the traditional resistance training but was less effective than 4 mm. These studies suggest that a higher vibration amplitude may be more effective than a lower amplitude. While Mester and colleagues (2005) did not measure EMG activity, the increases in strength and performance suggest the larger amplitude of 4 mm elicits the greatest muscular activation.

#### *Transmissibility of Whole Body Vibration Stimulus*

The term whole body vibration infers all skeletal muscles, active or inactive, are affected by the vibration stimulus, however there is no data concerning this ability. Therefore, it seems important to determine if WBV transmissibility from a platform does effectively stimulate an increase in upper body muscle activity. Rubin, Pope, Fritton, Magnusson, Hansson, and McLeod (2003) have reported that the degree of transmissibility to the spine decreases

with increasing knee bend in response to a 15-35 Hz vibration stimulus applied via a ground based platform. They reported that while the subjects stood erect (knees locked) vibration signals below 20 Hz were 100% transmissible through the hip, but frequencies between 25-35 Hz saw their transmissibility reduced to 80%. When the subjects stood on the platform in a relaxed stance (relaxed, knees straight) the transmissibility decreased to 60% and when the subjects stood with knees flexed to 20°, the transmissibility was further reduced to only 30% to the hips and spine.

The body's response to vibration depends on the frequency and amplitude of the vibration stimulus as well as the stiffness of the muscle or joint (Hagbarth & Eklund, 1966; Martin & Park, 1997; Nordin & Hagbrath, 1996). Muscles that are stretched are more sensitive to the vibration stimulus (Burke, Hagbarth, Löfstedt, & Wallin, 1976) and it is speculated that muscles with an initial level of contraction are more sensitive to vibration as well (Mester et al., 2002). Luo and colleagues (2005) have suggested that muscles closer to the vibration stimulus may see a greater increase in muscle activity as the more distal muscles may see the vibration attenuated. It is interesting to note that a vibrating cable attached to a weight stack generated dramatic improvements in upper body performance (Issurin et al., 1994) and Bosco et al. (1999a) demonstrated that training with a vibrating dumbbell resulted in significant increases in power, but currently all platform based WBV apparatus do not employ direct upper body vibration.

In summary, EMG is a useful tool to examine the ability of WBV to increase neuromuscular activity in isometrically active lower body muscle groups. The results to date indicate that varying frequencies and/or amplitudes may or may not be effective stimuli for changes in skeletal muscle performance and that WBV transmissibility to active or inactive upper body muscle groups is currently unknown. There is also no data indicating WBV effect on EMG activity during typical dynamic movements of upper or lower body skeletal muscles. Therefore, the general objectives of this investigation are to examine the effect of whole body vibration on muscle activity (using EMG) of a lower and upper body agonist and antagonist muscle pair during isometric and dynamic muscle contractions.

### *Objectives*

#### Part 1:

1. Identify the optimal frequency and amplitude combination that elicits the highest degree of muscular activation in agonist and antagonist muscles of the lower body while in an isometric semi-squat position.
2. Identify the optimal frequency and amplitude combination that elicits the highest degree of muscular activation in agonist and antagonist muscles of the lower body while performing dynamic squats

#### Part 2:

1. Identify the optimal frequency and amplitude combination that elicits the highest degree of muscular activation in agonist and antagonist muscles of the

upper body while in an isometric semi-squat position with an elbow joint angle of 90°.

2. Identify the optimal frequency and amplitude combination that elicits the highest degree of muscular activation in agonist and antagonist muscles of the upper body while performing dynamic bicep curls

## CHAPTER III

### METHODOLOGY

#### Subjects

Ten recreationally active young men from the University of Windsor volunteered as subjects for the present study (age,  $24.4 \pm 2.0$  years; height,  $177 \pm 7.3$  cm; weight,  $81.47 \pm 11.6$  kg). Subjects completed and passed a PAR-Q health survey (Appendix B) and were given full information on the possible risks of the study and all subjects gave their written informed consent, approved by the University of Windsor Research Ethics Board (REB#06-035), to participate in the experiment (Appendix A). Subjects were excluded from the study if they were diagnosed with diabetes, epilepsy, gallstones, kidney stones, acute inflammations, joint problems, cardiovascular diseases, joint implants, recent thrombosis, back problems such as hernia, tumors, recent operative wounds, or intense migraines as these are the contraindications indicated by the manufacturer of the platform.

#### Treatment Procedures

##### *Session #1: Familiarization Protocol*

Subjects were asked to participate in three sessions in the Human Kinetics building (RM 230). The first was a familiarization protocol. Basic subject characteristic data was first collected (age, height, weight) from each subject. Subjects were then asked to stand on the vibration platform with feet shoulder width apart, and a knee angle between  $110\text{--}130^\circ$  (where  $180^\circ$  was straight), and

arms at 90° flexion. The vibration platform (WAVE) (Figure 7) was turned on at a frequency of 25 Hz and an amplitude of 2 mm for 30 sec to allow the subject to experience the sensation of the vibration stimulus. Followed by a rest period of 1-2 minutes the frequency and amplitude was increased to allow the subject to experience the range of vibration stimuli the

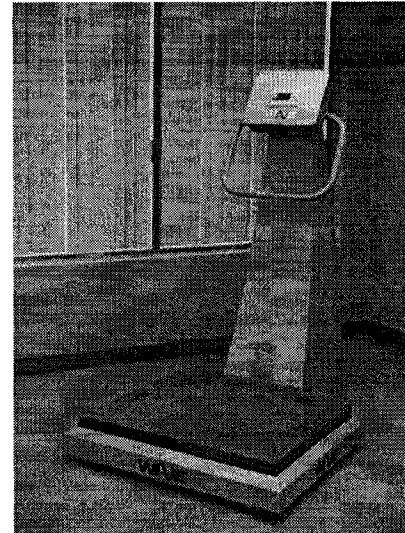


Figure 7 - The WAVE Platform.

platform could produce. During this time each subject was instructed to (1) only raise and lower their body position (full squat) to allow them to feel the sensation of various body positions on the vibrating platform and (2) flex and extend their biceps during the vibration stimulus (both actions were not done simultaneously).

Subjects were provided a demonstration of proper technique for the dynamic squat in this familiarization trial. Subjects were allowed to practice as many times as necessary until they performed the squats correctly and with comfort. All subjects learned the movement very quickly with no mention of fatigue or discomfort. Subjects received verbal instruction to complete the squats at a constant pace of 1 sec down and 1 sec up. The duration of this session was 15-20 minutes.

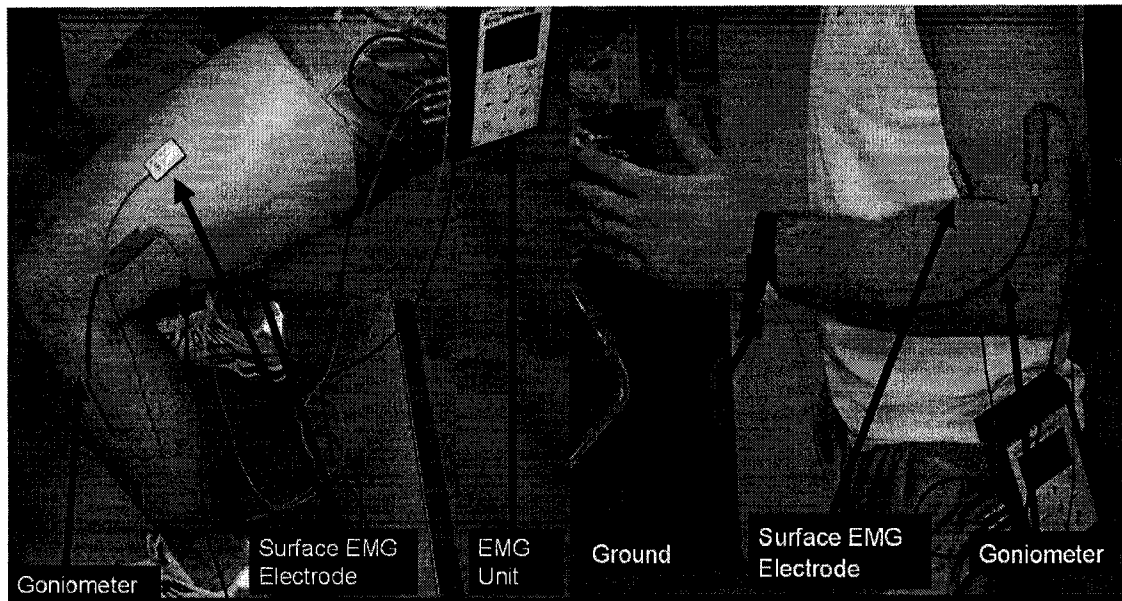


Figure 8 – Electrode and goniometer placement for recording muscle activity and joint angle respectively

Subjects were shown how and where the surface EMG electrodes and goniometers would be placed on each muscle and joint respectively, prior to data collection (Figure 8). The skeletal muscles recorded from were: vastus lateralis (quadriceps), biceps femoris (hamstrings), biceps brachii (bicep), and triceps brachii (tricep). These pairings of muscle groups were selected as they represent the primary active muscle group and inactive or antagonist muscle groups during a dynamic squat and barbell bicep curl (Seeley, Stevens, & Tate, 2000). Joint angle was collected to ensure subjects maintained the required position; not as an analytical measurement.

### *Session #2: Lower Body*

Subjects returned for the second session of the study and had all the EMG electrodes and goniometers attached as previously illustrated (Figure 8).



Subjects then performed a noise trial to determine the amount of baseline interference in the laboratory. This noise trial had the subject simply lay still for a one minute collection period. Subjects were then asked to perform MVE tests (Maximal Voluntary Exertion) for all muscle groups being analyzed. The vastus lateralis was measured while the subject was seated with knee angle at 90° and the subject attempted to extend their leg (push away from the chair) as forcefully as possible against resistance from a strap that prevented them from moving. The biceps femoris was measured in the same position and knee angle as the subject attempted to flex their leg (pull it towards the chair) while being resisted by a strap that prevented them from moving. The biceps and triceps were measured with elbow joint angle at 90° and had subject pull up as hard as they could (bicep) and push down as hard as they could (tricep) against resistance applied by the investigator that prevented them from moving. All MVE were isometric and were performed three times to ensure that the muscle's maximal activity was attained allowing a reference point for the EMG activity obtained during the vibration conditions.

The WBV stimulus was applied with a WAVE (Whole-body Advanced Vibration Exercise) (Slim and Shape, Windsor, Ontario, Canada) platform. This platform pre-weighs each subject while on the platform to ensure the vibration stimulus (frequency and amplitude) was not dampened by the weight of the individual. The platform generates a vertical vibration stimulus that oscillates uniformly up and down as described previously. The selected frequencies of the

vibration conditions were assigned at 25, 30, 35, 40, and 45 Hz with amplitudes of 2 and 4 mm.

In the Lower Body session, subjects were randomly exposed to 10

vibration conditions (Table 1) while

Table 1 – Whole Body Vibration Conditions

they performed an isometric semi-

Condition	Frequency (Hz)	Amplitude (mm)
1	25	2
2	25	4
3	30	2
4	30	4
5	35	2
6	35	4
7	40	2
8	40	4
9	45	2
10	45	4

squat (knee angle  $120^{\circ} \pm 10^{\circ}$ ) and dynamic squats. The subjects started by completing the isometric conditions first followed by the dynamic conditions. Each condition started with the subject squatting (isometrically or dynamically) on the platform for 15 sec without vibration, subjects continued squatting for 30 sec with vibration, and finally for 15 sec

without vibration. Therefore, each condition was actually 60 sec, but the subjects were only exposed to 30 sec of vibration. Foot position on the platform was maintained by marking it on the first trial and subjects were required to maintain that same foot position for all trials. The subjects received 5 min of rest between conditions to eliminate any fatigue that may have occurred and were blinded to the frequency and amplitude of the vibration exposure. After each condition

subjects were asked how intense the condition was using Borg's 10 point Rating of Perceived Exertion (RPE) scale. This session lasted approximately 2 hours.

### *Session #3: Upper Body*

The third and final session of this study again had the subjects fitted with EMG electrodes and goniometers as in the previous sessions. Subjects then performed the MVE test again to act as a reference for this session. Subjects were randomly exposed to the 10 vibration conditions in a semi-squat position (knee angle  $120^{\circ} \pm 10^{\circ}$ ) while maintaining an elbow angle of  $90^{\circ} \pm 5^{\circ}$  for the isometric condition and performed dynamic bicep curls for the dynamic condition. Each condition was identical to the previous session, with 15 sec completed without vibration, 30 sec with vibration, and 15 sec post vibration. Each subjects foot position was maintained identical to the lower body session with markers and they were also asked how intense each condition was on the same 10 point Borg RPE scale. The subjects received 5 min rest between exposures and were blinded to the vibration condition they were being exposed to, exactly like session 2. This session also lasted approximately two hours.

### EMG Analysis

The EMG signals from the four muscle groups (vastus lateralis, biceps femoris, biceps brachii, triceps brachii) were recorded with surface EMG electrodes (inter-electrode distance 10mm) fixed over the muscle bellies (Saitou, Masuda, Michikami, Kojima, & Okada., 2000). The EMG signal was sampled at

1000 Hz and was pre-amplified by a gain of 1000 (Biometrics DataLOG). The EMG was post processed using customized software (Labview, National Instruments, Austin, Texas) where the EMG data was extracted to determine the start and end points of the conditions. The interference EMG was dual passed Butterworth Filtered between 100-450 Hz using a 6<sup>th</sup> order filter which removed any noise caused by the frequency of the vibration platform or any electrical noise in the laboratory (Potvin & Brown, 2004). With the collection of pilot data and by examining different filter types the 100-450 Hz filter was selected as the most optimal in removing the noise of the platform while maintaining a large portion of the muscle activity. The data was then full wave rectified and smoothed with a low pass filter at 1.5 Hz. The noise was then subtracted and the data was divided by the MVE and multiplied by 100 to normalize to maximum.

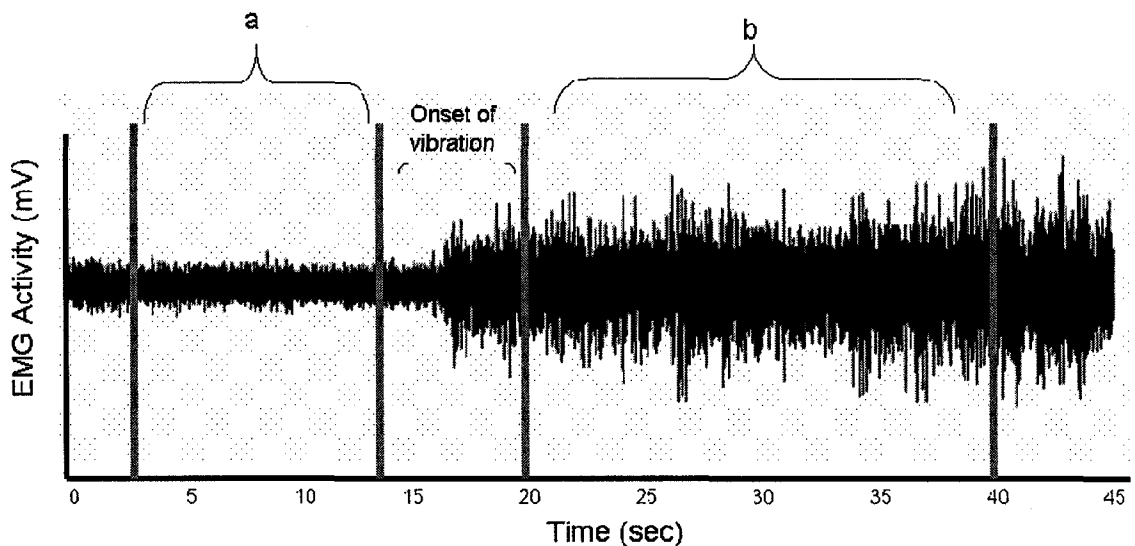


Figure 9 – Representative example of the EMG activity recorded from the vastus lateralis. a) No-vibration period, b) Vibration period, Onset of vibration is the time period where the vibration platform is turning on.

The MVE values were consistent with other data collected in the laboratory and in the literature. The EMG as a percentage (%)MVE was extracted to obtain the muscle activity during the pre-vibration and vibration portions of the data collection (Figure 9). The EMG root mean square (RMS) was then calculated and reported as mean  $\pm$  standard error (SE).

### Statistical Analysis

Statistical analysis investigated the effects of the independent variables of 5 frequencies and 2 amplitudes of vibration on the dependent variable (skeletal muscle response measured by EMG). One-way ANOVA's were used to investigate whether vibration resulted in significant increases in muscle activity over the no vibration condition (baseline). The EMGrms value from the 30 sec vibration period was compared to the 15 sec baseline no vibration period. Further analysis used a 5 x 2 (frequency x amplitude) Repeated Measures ANOVA to analyze the actual differences in muscle activity between the vibration period and the pre-vibration period to determine the effect of frequency and amplitude on muscle activity. Significance was evaluated at  $p < 0.1$  as this research project was very exploratory in nature. Post hoc tests were performed using Tukey's HSD tests.

## CHAPTER IV

### ANALYSIS OF RESULTS

#### Results

##### *Whole Body Effects on Lower Body Muscles*

##### *Isometric Condition*

During the isometric condition, muscle activity for the vastus lateralis (VL) was  $34.5 \pm 3.9\%$  maximal voluntary exertion (MVE) and for the biceps femoris (BF) was  $1.5 \pm 0.47\%$  MVE. Whole body vibration exposure resulted in increases in vastus lateralis muscle activity ranging from 0.6-6.7% MVE, with only the higher frequency and amplitude combinations resulting in statistically significant

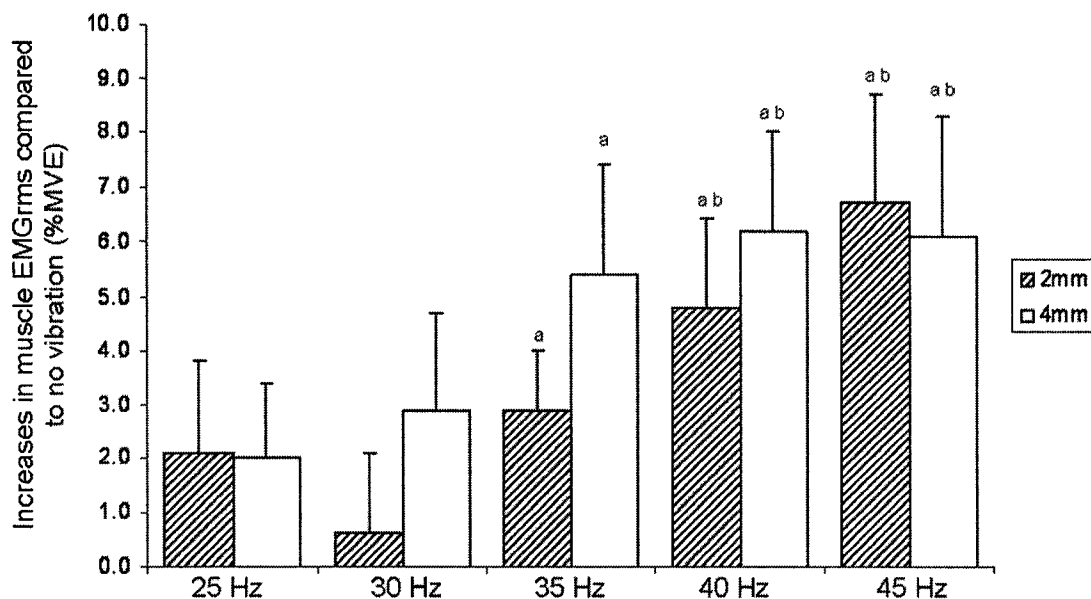


Figure 10 – Increases in vastus lateralis muscle activity with whole body vibration compared to no vibration during an isometric semi-squat. Values are mean  $\pm$  SE.

<sup>a</sup> – significantly greater than no vibration ( $p < 0.05$ )

<sup>b</sup> – significantly greater than 25 and 30 Hz ( $p < 0.05$ )

increases ( $p<0.05$ ) (Figure 10 symbol <sup>a</sup>). It is important to note that for all statistical comparisons each WBV stimuli was compared to its immediate preceding no vibration condition (see Figure 9).

When comparing the differences between the vibration and no vibration conditions the actual increases in muscle activity (%MVE) resulting from the vibration conditions demonstrated a significant frequency main effect and further post hoc analysis revealed the 40 and 45 Hz frequencies resulted in significantly greater muscle activity than the 25 and 30 Hz frequencies (Figure 10 symbol <sup>b</sup>).

In the biceps femoris, whole body vibration also led to increases in muscle activity as compared with no vibration ranging from 0.3-1.2%MVE with the higher

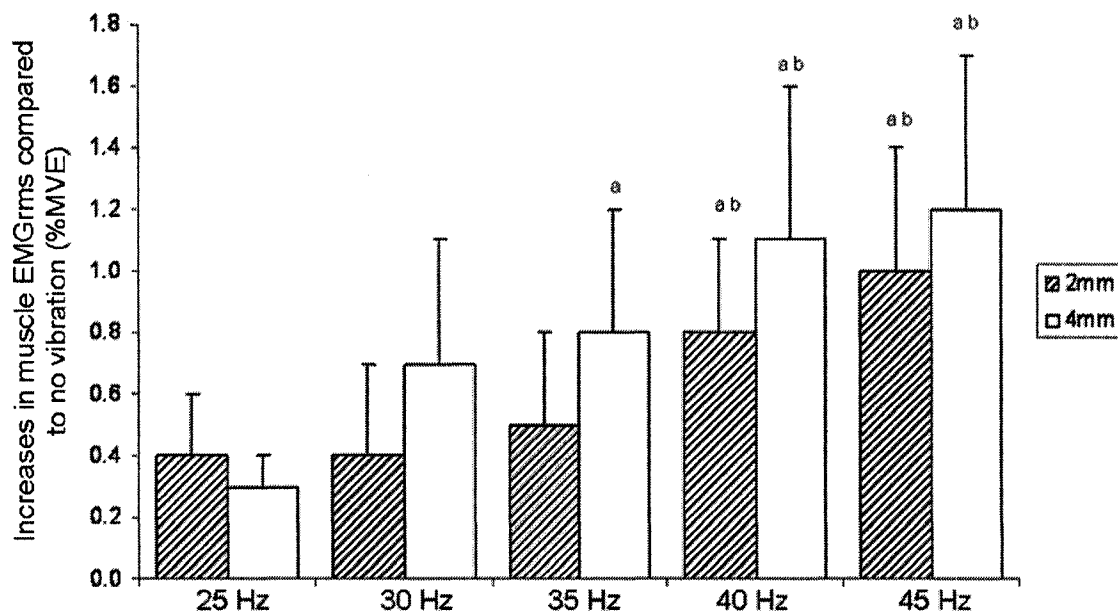


Figure 11 – Increases in biceps femoris muscle activity with whole body vibration compared to no vibration during an isometric semi-squat. Values are mean  $\pm$  SE.

<sup>a</sup> – significantly greater than no vibration ( $p<0.05$ )

<sup>b</sup> – significantly greater than 25 Hz ( $p<0.1$ )

frequencies and amplitudes resulting in statistically significant increases ( $p<0.05$ ) (Figure 11 symbol <sup>a</sup>).

During the comparison of the differences between the vibration and no vibration conditions, the resulting increases in muscle activity (%MVE) demonstrated significant frequency and amplitude main effects and post hoc analysis revealed the frequencies of 40 and 45 Hz elicited significantly greater muscle activity than the 25 Hz frequency (Figure 11 symbol <sup>b</sup>) and that the 4 mm amplitude resulted in significantly greater muscle activity than the 2 mm amplitude for the BF.

#### *Dynamic Condition*

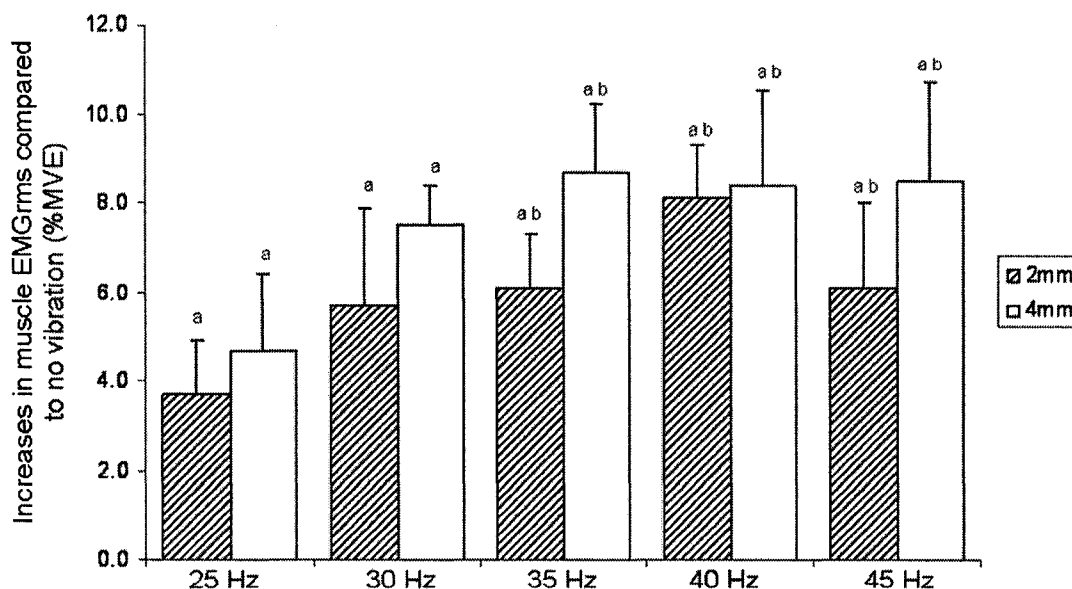


Figure 12 – Increases in vastus lateralis muscle activity with whole body vibration compared to no vibration during dynamic squatting.

Values are mean  $\pm$  SE.

<sup>a</sup> – significantly greater than no vibration ( $p<0.05$ )

<sup>b</sup> – significantly greater than 25 Hz ( $p<0.1$ )



During dynamic squats VL muscle activity with no vibration was  $52.5 \pm 3.7\%$ MVE and  $4.5 \pm 1.0\%$ MVE for the BF. The addition of whole body vibration resulted in increases in muscle activity ranging from 3.7-8.7%MVE in the VL as compared to no vibration and all increases were statistically significant ( $p < 0.05$ ) (Figure 12 symbol <sup>a</sup>) and in the BF WBV resulted in increases in muscle activity as compared with no vibration ranging from 0.4-2.0%MVE ( $p < 0.1$ ) (Figure 13 symbol <sup>a</sup>).

When comparing the differences between the vibration and no vibration conditions in the VL the actual increases in muscle activity (%MVE) resulting from the vibration conditions demonstrated significant frequency and amplitude main effects and were further analyzed to reveal the frequencies of 35, 40, and 45 Hz resulted in significantly greater muscle activity than the 25 Hz frequency (Figure 12 symbol <sup>b</sup>) and 4mm amplitude significantly increased muscle activity over 2mm.

In the biceps femoris, the higher frequencies and amplitudes resulted in significant increases in muscle activity ( $p < 0.1$ ) (Figure 13 symbol <sup>a</sup>). Comparison of the differences between the vibration and no vibration conditions revealed no main effects.

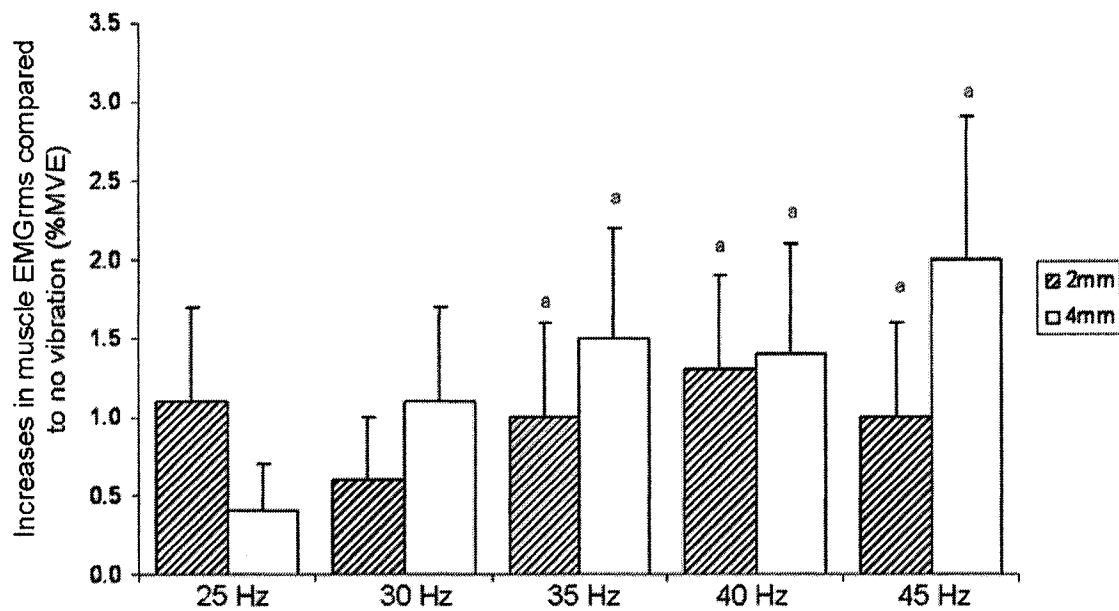


Figure 13 – Increases in biceps femoris muscle activity with whole body vibration compared to no vibration during dynamic squatting.

Values are means  $\pm$  SE.

<sup>a</sup> – significantly greater than no vibration ( $p < 0.1$ )

### *Whole Body Vibration Effects on Upper Body Muscles*

#### *Isometric Condition*

In the isometric condition, biceps brachii (BB) muscle activity with no vibration was  $2.5 \pm 0.5\%$ MVE and  $0.8 \pm 0.1\%$ MVE in the triceps brachii (TB).

Exposure to whole body vibration did not result in any significant increases in muscle activity in the BB when compared to no vibration (Table 2). In the TB, all whole body vibration conditions resulted in significant increases in muscle activity when compared to no vibration ( $0.3\text{--}0.7\%$ MVE;  $p < 0.01$ ; Table 2 symbol <sup>a</sup>).

Table 2 – Increases in upper body muscle EMGrms with whole body vibration during the isometric and dynamic conditions.

<sup>a</sup> - significantly greater than no vibration ( $p < 0.1$ )

<sup>b</sup> - significantly greater than 25, 30, 35, and 40 Hz ( $p < 0.05$ )

Condition	Muscle	25 Hz 2 mm	25 Hz 4 mm	30 Hz 2 mm	30 Hz 4 mm	35 Hz 2 mm	35 Hz 4 mm	40 Hz 2 mm	40 Hz 2 mm	45 Hz 2 mm	45 Hz 4 mm
Isometric	Biceps Brachii	0	0	0	0	0	0	0	0.2	0.1	0
	Triceps Brachii	0.3 <sup>a</sup>	0.3 <sup>a</sup>	0.3 <sup>a</sup>	0.4 <sup>a</sup>	0.3 <sup>a</sup>	0.3 <sup>a</sup>	0.3 <sup>a</sup>	0.4 <sup>a</sup>	0.7 <sup>a b</sup>	0.6 <sup>a b</sup>
Dynamic	Biceps Brachii	0.8 <sup>a</sup>	0.6	0.6 <sup>a</sup>	0.6 <sup>a</sup>	0	0.2	0.2	0.8	0.2	0.7 <sup>a</sup>
	Triceps Brachii	0.4 <sup>a</sup>	1.0 <sup>a</sup>	0.2 <sup>a</sup>	1.0 <sup>a</sup>	0.5	0.7 <sup>a</sup>	0.5 <sup>a</sup>	1.0 <sup>a</sup>	0.7 <sup>a</sup>	1.0 <sup>a</sup>

When comparing the actual differences between the vibration and no vibration conditions the increases in muscle activity (%MVE) in the TB demonstrated significant frequency and amplitude main effects. Analysis revealed that the 45 Hz frequency resulted in significantly greater muscle activity than all other frequencies (25, 30, 35, and 40 Hz) (Table 2 symbol <sup>b</sup>) and that the 4 mm amplitude resulted in significantly greater muscle activity than the 2mm amplitude.

#### *Dynamic Bicep Curl Condition*

During dynamic bicep curls, muscle activity for the BB was  $4.3 \pm 0.7\%$ MVE and  $3.6 \pm 0.4\%$ MVE for the TB. The addition of whole body vibration resulted in increases in muscle activity in the BB when compared to no vibration ranging from 0.2-0.8%MVE. Statistical significance were observed for only 4 of the 10 conditions ( $p < 0.05$ ) (Table 2 symbol <sup>a</sup>).

Comparison of the differences between the vibration and no vibration conditions in the BB revealed WBV resulted in a significant amplitude main effect where post hoc analysis demonstrated that the 4 mm amplitude resulted in significantly more muscle activity than the 2 mm amplitude. In the TB, WBV led to increases in muscle activity over no vibration ranging from 0.2-1.0%MVE with most WBV stimuli resulting in significant increases ( $p < 0.1$ ) (Table 2 symbol <sup>a</sup>).

When comparing the differences between the vibration and no vibration conditions there was a significant amplitude main effect and post hoc analysis

revealed the 4 mm amplitude resulted in significantly greater muscle activity than the 2 mm amplitude.

## Discussion

Whole body vibration training has been reported to result in improvements in muscle strength (Bosco et al., 1999b; Delecluse et al., 2003; Issurin et al., 1994; Roelants et al., 2004a,b; Rønnestad, 2004; Torvinen et al., 2002a,c; Verschueren et al., 2004) and muscle power (Bosco et al., 1999a,b; Cochrane & Stannard, 2005; Delecluse et al., 2003; Issurin & Tenenbaum, 1999; Roelants et al., 2004b; Rønnestad, 2004; Torvinen et al., 2002a,c, 2003). These increases in muscle performance are theorized to be the result of the WBV stimulus eliciting involuntary reflex contractions during vibration that result in improvements in voluntary skeletal muscle performance subsequent to the training perturbation. These involuntary contractions are thought to be the result of the tonic vibration reflex (TVR) (Figure 3), a spinal reflex that is responding to changes in muscle length due to the frequency and/or amplitude displacements generated from the WBV platform. This reflex involuntarily produces rapid adjustments in muscle length caused by the WBV stimulus resulting in an increase in skeletal muscle activity and improvements in voluntary skeletal muscle activation.

WBV frequencies ranging from 15- 50Hz (Cardinale & Lim, 2003; Torvinen et al., 2002a) and amplitude changes varying from 1-105mm (Delecluse et al., 2005; Rittweger et al., 2000) have been utilized in the literature with varying outcomes. A review of the literature currently indicates that to date there is no

consensus on which combination(s) of frequency and/or amplitude is the most effective means to increase skeletal muscle activity thereby resulting in improvements in voluntary muscle performance. The present study attempted to determine the optimal vertical vibration stimulus (frequency and amplitude) to activate upper and lower body agonist/antagonist muscle pairs during three distinctive actions: an isometric semi-squat, unloaded dynamic leg squats, and bilateral bicep curls.

### *Whole Body Vibration Effects on Lower Body Muscles*

#### *Isometric Condition*

During an isometric semi-squat, muscle activity with no vibration for the vastus lateralis (VL) was 34.5% of maximal voluntary exertion (MVE) and 1.5%MVE for the biceps femoris (BF). In general, our results demonstrated that WBV resulted in an average 4%MVE increase in VL muscle activity (range 0.6-6.7%MVE, Figure 10) and a 0.7%MVE increase in BF muscle activity (range 0.3-1.2%MVE, Figure 11). While select WBV stimuli resulted in statistically significant increases in muscle activity these increases relative to muscle activity without vibration may be functionally insignificant. These relatively small increases in muscle activity are expressed as a percentage of MVE and were subjectively confirmed during WBV as an average value of 3 was reported using Borg's 10 point rating of perceived exertion (RPE) for intensity during all vibration frequencies and amplitudes.

In contrast, Roelants et al. (2006) reported average increases in muscle activity for the vastus lateralis of 92.5%, rectus femoris of 115%, vastus medialis of 102%, and gastrocnemius of 301.3% as a percentage increase compared to the control values in a semi-squat position with a vertical vibration stimulus of 35Hz 2.5mm [PowerPlate]. While their increases in VL muscle activity appear to be dramatically different from our average result of 4% it is important to note that our results are based on the EMGrms value as a percentage of MVE, not as a percentage over the control value. Expressing the increase in muscle activity as a percentage increase over the control value as Roelants et al. (2006) have leads to an overestimation of the effects of WBV. Expressing our data as a percentage of MVE is a value we believe to be more representative of functional muscle activity changes. For example, recalculating Roelants et al. (2006) data based on MVE, muscle activity increased only 26% in the vastus lateralis, 15% in the rectus femoris, 21% in the vastus medialis, and 12% in the gastrocnemius muscle.

Additionally during pre-testing, we determined it was important to band-pass filter our EMG signal between 100-450 Hz to ensure the electrical signals generated inherently by the WBV platform were eliminated, yet still retaining the major portion of the required EMG muscle activity for analysis (Potvin & Brown, 2004). This is important as the frequency (Hz) component of the oscillating platform would contribute to the interference signal and contribute to the calculated increases in EMG as a result of the vibration perturbation. Roelants et

al. (2006) did not indicate if they filtered out the vibration frequencies generated by the platform.

Increases in isometric VL EMGrms muscle activity of 34% has also been reported by Cardinale & Lim (2003) using a reciprocating displacement vibration platform [Galileo] with the peak increase in muscle activity at 30 Hz. While this data is not directly comparable to our results due to the differences in the vibration platform used (Amonette, Abercromby, Hinman, & Paloski, 2006 unpublished), there data also indicates WBV increases EMG muscle activity. Regardless of the extent of differences, these studies by Cardinale & Lim (2003) and Roelants et al. (2006) as well as the present research all demonstrate an increase in isometric leg muscle activity during WBV.

Our data also indicates a general trend towards increased isometric muscle activity as the frequency (Hz) and amplitude (mm) of the vibration stimulus intensified (see Figures 10 & 11). Specifically, the 40 and 45 Hz frequencies resulted in significantly more isometric muscle activity than the lower frequencies (25 and 30Hz) with a peak increase in VL muscle activity of 6.7%MVE elicited from the 45Hz 2mm condition and in the BF of 1.2%MVE from 45Hz 4mm. The results from the 45Hz frequency in the present study may suggest that muscle activity increases then plateaus or even begins to decrease at frequencies at or beyond the 45 Hz range. For example, in the VL during an isometric semi-squat the muscle activity decreases from the 45 Hz 2mm condition to the 45 Hz 4 mm condition. In a recent review by Luo et al. (2005), the authors suggested the most effective frequencies to use in WBV training are



between 30-50 Hz and Mester et al. (2002) have recommended that frequencies below 20 Hz are dangerous physiologically and frequencies above 50 Hz may result in a larger attenuation by muscle tissue. In general, our data indicates that as frequency increases so does muscle activity and similarly as amplitude increases so follows muscle activity. An examination of the various combinations of frequency and amplitude data from our study reveals that amplitude has little effect at the low (25 Hz) and high (45 Hz) frequencies, however the mid range frequencies (30,35, & 40Hz) seem to be much more influenced by changes in amplitude. This observation is still preliminary and warrants further research efforts but is in agreement with a previous report by Mester and colleagues (2005) who demonstrated WBV training [PowerPlate] with 4 mm resulted in a greater increase in strength and performance than a vibration stimulus with 2 mm amplitude.

The small increase in muscle activity with WBV in an unloaded isometric semi-squat may be due to the fact that the vertical vibration stimulus was too small to disturb the muscles/body position enough to create a dramatic response in muscle activity. The small increases in muscle activity may have also been due to the unloaded isometric semi-squat position causing a poor transmissibility of the vibration stimulus. With this in mind we believe the addition of an external load which would increase muscle tension during WBV may elicit larger increases in isometric muscle activity. This is based on the principle that if a muscle is contracted (Mester et al., 2002) and lengthened (Burke et al., 1976) the resulting stiffening of a joint (Hagbarth & Eklund, 1966; Martin & Park, 1997;

Nordin & Hagbarth, 1996) should lead to an improvement in the transmissibility of the vibration stimulus to the muscle. It is interesting to note that the platform in the current study comes with adjustable nylon hand straps that can be used isometrically to increase the stiffness of the upper and lower body which may result in greater increases in isometric muscle activity than seen in the current data. The effectiveness of these adjustable straps to transmit the vibration stimulus and potentially improve isometric muscle activity is a planned research project for this laboratory.

Currently there are no isometric studies examining the use of a vertically vibrating stimulus to enhance performance. However, studies examining the effect of a reciprocating displacement vibration stimulus on muscle performance in isometric conditions suggest that WBV may result in improvements in muscle performance. Work by Bosco et al. (1999b) report improvements in muscle power with WBV exposure to a vibration stimulus of 26 Hz, 10 mm [Galileo] during a semi-squat position with 100° knee angle. However, De Ruiter et al. (2003) with a stimulus of 30 Hz 8 mm [Galileo] during a semi-squat position of 110° knee angle and Cochrane et al. (2004) with 26 Hz, 11 mm [Galileo] using different isometric positions (standing upright, squatting to 90° knee angle, squatting to 90° knee angle with feet externally rotated, and single leg standing with a knee angle of 90°) demonstrated no benefits with exposure to a WBV stimulus. These results suggest the ability of a reciprocating WBV training regime with strictly isometric positions to improve muscle performance are

unclear to date and strengthen the need to examine the effect of isometric studies with a vertical vibration platform.

### *Dynamic Squat Condition*

The use of dynamic unloaded squats was to examine if the dynamic skeletal muscle action enhanced the effects of WBV on EMG muscle activity. The isometric semi-squat VL muscle activity without WBV was 34.5%MVE and 1.5%MVE for the BF and with the addition of dynamic squats with no vibration raised VL activity to 52.5%MVE and BF activity to 4.5%MVE. With the addition of WBV, increases in VL muscle activity during unloaded squats ranged from 3.7-8.7%MVE (Figure 12) and 0.4-2.0%MVE in the BF (Figure 13). Whole body vibration significantly increased VL muscle activity at all vibration combinations (Figure 12) but only select WBV stimuli had significant BF effects (Figure 13). The average increases due to WBV while performing dynamic squats was only 6.8%MVE in the VL and 1.2%MVE in the BF and may be functionally small though are similar to the average increases in the isometric condition of 4%MVE for the VL and 0.7%MVE for the BF. Furthermore, these small increases were subjectively confirmed as an average value of 4 was reported during dynamic squats using Borg's 10 point RPE for intensity during all vibration frequencies and amplitudes.

The increase in muscle activity from the isometric to dynamic condition was expected, however the small increase during dynamic squats with WBV was unexpected. We had expected that the addition of the dynamic squats with WBV

would have increased muscle activity much more than the isometric position because the upper body weight during movement would activate muscle groups and stiffen joints (Burke et al., 1976; Mester et al., 2002), thereby improving transmissibility. This we thought should have translated into a more meaningful increase in muscle activity while performing a dynamic contraction during WBV. We speculate that the addition of an external load while performing dynamic contraction during WBV might be required to further increase activation of muscle groups and joint stiffness and lead to a more functionally significant increase in muscle activity during WBV. The vibration platform used in this study would be ideal for investigating the effect of loaded contractions during WBV as it eliminates any reduction in the vibratory stimulus due to the subjects weight or any external load by pre-weighing subjects the load and adjusting the vibration, a feature unique to this experimental platform. This is a concept that is currently being investigated by our laboratory.

Our dynamic squat results also demonstrate a general tendency towards an increased amount of muscle activity as the frequencies and amplitudes of the vibration stimulus increase which was similar to the isometric WBV condition. Specifically, the higher vibration frequencies of 35, 40, and 45 Hz resulted in significantly greater increases in muscle activity than the 25 Hz frequency in the VL (Figure 12). In the BF, only the higher combinations of frequency and amplitude resulted in significantly greater increases than no vibration (Figure 13). An 8.7%MVE peak increase in VL muscle activity was elicited by the 35 Hz 4 mm condition and a 2.0%MVE peak increase in the BF by the 45 Hz 4 mm

vibration condition. Similar to the isometric condition, further analysis of the different combinations of frequency and amplitudes from the present data shows that while amplitude has a minimal effect at the low (25Hz) and high (45Hz) frequencies, it seems to have a greater effect on the mid range frequencies (30,35, & 40 Hz). These are initial findings and need further clarification, particularly in light of the rather small increases in muscle activity with WBV during unloaded dynamic activity.

Interestingly, our results demonstrating the greatest increases in muscle activity in a frequency range of 35-45 Hz (Figure 12) are similar to other studies examining the effects of a vertically oscillating WBV stimulus on performance enhancement. Studies reporting increases in performance (Delecluse et al., 2003; Mester et al., 2005; Roelants et al., 2004a,b; Torvinen et al., 2002b, 2003; Verschueren et al., 2004) have used frequencies ranging from 25-50 Hz and reported improvements in vertical jump from 7.2-16% (Delecluse et al., 2003; Roelants et al., 2004b; Rønnestad, 2004; Torvinen et al., 2002b, 2003), 1-RM of 32.4% (Rønnestad, 2004), isometric strength from 1.9-24.4% (Delecluse et al., 2003; Mester et al., 2005; Roelants et al., 2004a,b; Torvinen et al., 2002b, 2003; Verschueren et al., 2004), and in dynamic strength from 9-22.2% (Delecluse et al., 2003; Mester et al., 2005; Roelants et al., 2002b; Verschueren et al., 2004). These increases in muscle performance following WBV are theorized to be due to the TVR causing an increase in MU synchronization (Nazarov and Spivak, 1985) though current research has demonstrated that MU synchronization does not result in increases in muscle strength but does lead to increases in muscle

activity (Enoka & Fuglevand, 2001). Other speculations are the TVR causing a decrease in the recruitment thresholds of MUs compared to voluntary contractions (Romaiguere et al., 1993) and/or activating a larger portion of the MU pool (Issurin & Tenenbaum, 1999). It has also been speculated that performance gains with WBV training are due to a more effective production of force due to a more efficient use of the sensory reflex pathways (Delecluse et al., 2003). While improvements in physical performance and how they occur are beyond the scope of this research project they do require future investigations.

In our experiment we exposed subjects to 30 sec of vibration followed by 5 minutes of rest to ensure fatigue did not become a critical factor in muscle activity. To date however, the most effective duration (time) of exposure to a WBV stimulus during training has not been identified. Torvinen et al. (2002a,c) examined muscle activity (EMGrms) during WBV while subjects performed a light exercise routine (dynamic and isometric contractions) for 4 consecutive minutes and found no increases in VL muscle activity when comparing minute 4 to minute 1, but did find increased muscle activity in the soleus, gastrocnemius, and gluteus medius. Another study by Rittweger et al. (2003) reported that dynamic squatting with an external load of 40% body weight with vibration resulted in significantly faster times to exhaustion (349 sec) than squatting without vibration (515 sec). Both studies indicate that prolonged exposure (> 4min) to a WBV stimulus may result in faster muscle fatigue. The importance of time of exposure to WBV is also supported by their reported shifts in skeletal muscle mean power frequency and median power frequency values (Torvinen et al., 2002a,c;

Rittweger et al., 2003), both indices of muscle fatigue. There is no currently established optimal duration (time) of WBV stimulation or information on the effect of time of exposure on isometric or dynamic muscle activity at any frequency or amplitude and does require future investigation. Determination of an optimal exposure to WBV as well as appropriate rest intervals and number of sets to perform with WBV all need further investigation.

### *Whole Body Vibration Effects on Upper Body Muscles*

#### *Isometric Condition*

In the Isometric condition, subjects were instructed to maintain an elbow joint angle of  $90^{\circ} \pm 5^{\circ}$  in a semi-squat position and muscle activity with no vibration for the biceps brachii (BB) was 2.5%MVE and 0.8%MVE for the triceps brachii (TB). Our results demonstrated that all WBV conditions resulted in significant muscle activity increases in the triceps brachii (TB) muscle with a range of 0.3-0.7%MVE and no significant increases in the biceps brachii (BB) muscle over no vibration (see Table 2). Further analysis of the muscle activity in the TB demonstrated the 45 Hz frequency resulted in significantly greater muscle activity than all other frequencies (25, 30, 35, and 40 Hz) (Table 2) with the 45 Hz 2 mm condition resulting in a peak increase in muscle activity of 0.7%MVE. The average increase in the TB (0.4%MVE) though statistically significant is for all practical purposes extremely small which is similar to our data reports for the lower body muscles. Subjects in the study reported that they could not feel any

platform vibration being transmitted to the upper body muscles as an average value of 0 was reported using Borg's 10 point RPE during all conditions.

#### *Dynamic Bicep Curl Condition*

During unloaded dynamic bicep curls the average muscle activity with no vibration of the BB was 4.3%MVE and 3.6%MVE in the TB. With select WBV stimuli, BB skeletal muscle activity increases ranged from 0-0.8%MVE and for TB ranged from 0.2-1.0%MVE during dynamic bicep curls compared to no vibration (Table 2). Additional analysis also revealed that the 4 mm amplitude displacement resulted in greater muscle activity than the 2 mm amplitude. The small increases in %MVE for the BB and TB were similar to those calculated for the isometric condition and were of little functional value. These small increases in muscle activity were subjectively confirmed with an average value of 1 on the Borg 10 point RPE scale being reported during all vibration conditions.

To date this is the first study to examine the isometric and dynamic EMG muscle activity of upper body muscles with vibration applied via a vertically displaced platform. Our results demonstrate a minimal effect of a vertically based vibration stimulus on unloaded isometric and dynamic upper body muscle activity and suggest a dramatic reduction of the vibratory stimuli to the upper body as compared to the lower body. This poor transmission to the upper body is supported by Rubin et al. (2003) who reported that the ability of a WBV stimulus from a ground based platform (15-35 Hz) to pass through the hips and spine was about 30% when standing with knees bent (20° flexion). Luo and



colleagues (2005) have suggested that muscles closer to the vibration stimulus may see a greater increase in muscle activity and fatigue as the more distal muscles may see the vibration attenuated. Mester et al. (2002) also speculated that both the frequency and amplitude of the vibration stimulus may be reduced in a non-linear fashion by the body's soft tissues. What this suggests is that the vibratory stimulus is dramatically reduced as it goes up the body when using a vertical displaced vibratory platform resulting in the muscle groups farther from the platform receiving an insufficient stimulus to cause any appreciable increase in muscle activity (Luo et al., 2005).

As previously discussed, to improve the effectiveness of WBV increasing the upper and lower joint and muscle stiffness by subjects contracting isometrically or dynamically with a weighted barbell should increase the transmissibility of the vibration to the upper body. This concept is currently being investigated in our laboratory as several studies examining WBV training on the upper body with loaded contractions have reported increases in performance (Bosco et al., 1998; Issurin et al., 1994; Issurin & Tenenbaum, 1999).

Alternatively, one could also consider standing on a vibrating platform with little or no knee flexion to reduce the attenuation of the vibration stimuli, but the extreme discomfort associated with this body position makes it impractical to implement.

It is interesting to note that an alternative way to improve the transmissibility of a vibratory stimuli to the upper body is to use a more direct vibratory stimulus. A weighted vibrating dumbbell [Galileo] has been designed

specifically for upper body muscles and Bosco et al. (1999a) testing it reported that a 30 Hz 6 mm vibrating dumbbell held in a semi-flexed position resulted in a significant increase in bicep brachii EMGrms (225%) and a significant increase in muscle power. Furthermore, Issurin & Tenenbaum (1999) demonstrated that performing bicep curls with a bar attached to a vibrating cable assembly (Figure 4) significantly increased strength and suggested that a vibration frequency between 40-50 Hz may be the best to activate muscles distal to the vibration stimulus. We have shown that no frequency or amplitude generated via a vertically vibrating WBV platform is able to effectively increase EMG activity of upper body muscles. These results support the need to determine an effective means of improving activation of upper body muscles during vertically displaced WBV. As previously suggested simply activating the upper and/or lower body muscle groups isometrically and/or dynamically might effectively serve this purpose. Utilization of the platform's adjustable nylon hand straps isometrically to increase activation of both upper and lower body muscles might also prove to be an effective way to improve vibration effects and is currently being investigated in our laboratory. Another method to improve the effect of WBV on upper body muscle activation is to perform upper body exercises, such as push-ups and tricep dips, directly on the platform.

## CHAPTER V

### SUMMARY/CONCLUSION AND RECOMMENDATIONS

#### Summary/Conclusion

Whole body vibration has been used as an effective training method to improve skeletal muscle strength and performance. These increases in muscle performance are theorized to be the result of the WBV stimulus eliciting involuntary reflex contractions via the tonic vibration reflex that result in improvements in voluntary skeletal muscle performance. The WBV stimulus utilizes vertically oscillating displacements characterized by a frequency (number of oscillations per sec) expressed in Hz and an amplitude (amount of vertical displacement) measured in mm. The literature on WBV effects on the lower body indicates that varying frequencies and amplitudes may be an effective stimuli for evoking significant increases in isometric muscle activity and performance. However, the effects of the WBV stimulus to activate upper body skeletal muscles is unknown. There is also no data indicating the WBV effect on EMG activity during dynamic movements of the upper or lower body.

The purpose of this research project was to identify which WBV combination of frequency and amplitude resulted in the highest degree of EMG muscle activity in agonist and antagonist muscles in the upper and lower body during unloaded isometric and dynamic contractions.

The results demonstrated that WBV led to statistically significant increases in upper and lower body skeletal muscle activity during isometric and dynamic contractions compared to no vibration. The results could not identify a single

optimal vibration stimulus combination, but indicated that the higher frequencies between 35-45 Hz and the higher amplitude of 4 mm appear to be the most effective in increasing skeletal muscle activity. However, these increases in muscle activity may not lead to any functionally significant improvements in performance, especially with the vibratory stimulus having little effect on the upper body. Overall, the dynamic EMG data did show higher muscle activity and greater increases in EMG than the isometric condition suggesting when doing WBV training it is best to include dynamic activities.

### Recommendations

Recommendations for future study:

1. Determine the effect of varying external loads on the upper and lower skeletal muscle activity during both isometric and dynamic contractions with WBV.
2. Determine if isometric contractions using the tethered hand held adjustable nylon straps will improve transmissibility of the WBV stimulus and lead to increases in upper and lower body skeletal muscle activity
3. Determine the optimal duration (time) for WBV exposure and recovery time between exposures to prevent muscle fatigue

4. Determine if performing upper body exercises ( ie. push-ups and tricep dips) directly on the WBV platform increases upper body skeletal muscle activity
5. Determine the most effective number of repetitions and sets to do with an external load for optimal performance gains using WBV

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## APPENDICES

### APPENDIX A

#### Ethics Approval



Today's Date: February 21, 2006  
Principal Investigator: Mr. Tom Hazell  
Department/School: Kinesiology  
REB Number: 06-035  
Research Project Title: The effect of whole body vibration on muscular activation  
Clearance Date: February 16, 2006  
Project End Date: May 31, 2006  
  
Progress Report Due:  
Final Report Due: May 31, 2006

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This is to inform you that the University of Windsor Research Ethics Board (REB), which is organized and operated according to the *Tri-Council Policy Statement* and the University of Windsor *Guidelines for Research Involving Human Subjects*, has granted approval to your research project on the date noted above. This approval is valid only until the Project End Date.

A Progress Report or Final Report is due by the date noted above. The REB may ask for monitoring information at some time during the project's approval period.

During the course of the research, no deviations from, or changes to, the protocol or consent form may be initiated without prior written approval from the REB. Minor change(s) in ongoing studies will be considered when submitted on the Request to Revise form.

Investigators must also report promptly to the REB:

- a) changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
- b) all adverse and unexpected experiences or events that are both serious and unexpected;
- c) new information that may adversely affect the safety of the subjects or the conduct of the study.

Forms for submissions, notifications, or changes are available on the REB website: [www.uwindsor.ca/reb](http://www.uwindsor.ca/reb).

We wish you every success in your research.

A handwritten signature in cursive script that reads "Maureen Muldoon".

Maureen Muldoon, Ph.D.  
Chair, Research Ethics Board

cc: Dr. Kenji Kenno, Kinesiology  
Linda Bunn, Research Ethics Coordinator

This is an official document. Please retain the original in your files.

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TELEPHONE 519/255-7000 (2916) FAX 519/971-8667 WEB [www.uwindsor.ca/reb](http://www.uwindsor.ca/reb)

## APPENDIX B

### PAR-Q Health Survey

## PAR-Q & YOU

Physical Activity Readiness  
Questionnaire – PAR-Q (Revised 1994)

#### (A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below.

If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

#### YES

- ☐ ☐ 1 Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
- ☐ ☐ 2 Do you feel pain in your chest when you do physical activity?
- ☐ ☐ 3 In the past month, have you had chest pain when you do physical activity?
- ☐ ☐ 4 Do you lose your balance because of dizziness or do you ever lose consciousness?
- ☐ ☐ 5 Do you have a bone or joint problem that could be made worse by a change in your physical activity?
- ☐ ☐ 6 Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
- ☐ 7 Do you know of any other reason why you should not do physical activity?

#### If you answered

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want – as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

#### DELAY BECOMING MUCH MORE ACTIVE:

- If you are not feeling well because of temporary illness such as a cold or a fever – wait until you feel better, or
- If you are or may be pregnant – talk to your doctor before you start becoming more active

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively.

Please note: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

**Informed Use of the PAR-Q:** The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if no doubt after completing this questionnaire, consult your doctor prior to physical activity.

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

NAME: \_\_\_\_\_  
SIGNATURE: \_\_\_\_\_  
SIGNATURE OF PARENT: \_\_\_\_\_  
or GUARDIAN (for participants under the age of majority)

DATE: \_\_\_\_\_  
WITNESS: \_\_\_\_\_

**You are encouraged to copy the PAR-Q but only if you use the entire form**

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Health  
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Santé  
Canada

## APPENDIX C

### Subject Consent Forms



#### CONSENT TO PARTICIPATE IN RESEARCH

Title of Study: **The Effect of Whole Body Vibration on Muscular Activation**

You are being asked to participate in a research study conducted by Tom Hazell, Dr. J. Jakobi, and Dr. K. Kenno from the department of Kinesiology at the University of Windsor. The Results of this study will contribute to the completion of a Master's graduate thesis.

If you have any questions or concerns about the research, please feel free to contact Tom Hazell at (519) 253-3000 x 4049 or Dr. Kenji Kenno at (519) 253-3000 x 2444.

#### PURPOSE OF THE STUDY

The purpose of this study is (1) to determine the appropriate vibration frequency (times per second) and displacement (mm of vertical displacement) to activate the greatest amount of muscular activation and (2) to determine the effect of whole body vibration on dynamic muscle contractions (squat and arm curl). Whole body vibration is applied through a platform that vibrates at a given frequency and displacement. The vibration sensation is similar to a high-intensity massager that is applied from a platform you are standing on and has been described as comfortable and relaxing

#### PROCEDURES

If you volunteer to participate in this study, we would ask that you do the following things:

1. Complete a health survey (PAR-Q) to assess your current physical capability.
2. You will be asked to report to the lab where you will receive an introduction to the whole body vibration platform. You will be asked to stand in different positions and perform different movements on the platform to get used to its sensation. This session will take no longer than 30 minutes.
3. Session 2: This session will be approximately 1 week after session 1 and the investigator will apply surface EMG electrodes (small discs) to muscles of the upper and lower body (i.e. arm and leg), as well as goniometers to the knee and elbow joint (measures joint angle). You will then perform MVE (maximal voluntary exertions) for each muscle being analyzed. These are completed by contracting that muscle as maximally as possible against resistance provided by the investigator. These MVE will provide a reference point for your maximal muscle activity. You will be asked to maintain a static semi-squat position (knee angle  $120^{\circ} \pm 10^{\circ}$ ) and perform dynamic squats for 30 sec each while being exposed randomly to the 10 whole body vibration conditions. You will receive a 5 min rest period between exposures. You will be asked to perform a no vibration pre condition and a no vibration post condition to act as a control value. This session will take approximately 2 hours.
4. Session 3: The third session will take place approximately 1 week after session 2 (depending on subject scheduling) and the investigator will apply surface EMG electrodes to muscles of the upper and lower body as well as goniometers to the knee and elbow joint. You will then perform MVE trials, identical to session 2. You will then be asked to stand in a static semi-squat position (knee angle  $120^{\circ} \pm 10^{\circ}$ ) with an elbow joint angle of  $90^{\circ} \pm 5^{\circ}$  and perform dynamic bicep curls for 30 sec each while being exposed randomly to the 10 whole body vibration conditions. You will receive a 5 min rest period between exposures. This session will take approximately 2 hours.

All sessions will be conducted in the Exercise Physiology Lab (Rm 230) on the second floor of the Human Kinetics Building. Results from this experiment will be available by July 1<sup>st</sup>, 2006 on the University of Windsor Research Ethics Board website: [www.uwindsor.ca/reb](http://www.uwindsor.ca/reb) under Study Results. They will also be printed in the final thesis that will be available in the front office of the Human Kinetics Building

#### POTENTIAL RISKS AND DISCOMFORTS

There are minimal risks associated with this study. Muscle soreness and/or fatigue is a possibility but it is not anticipated

with the duration of the applied whole body vibration stimulus being short (30 sec) and the extended rest periods provided (5 minutes).

#### POTENTIAL BENEFITS TO SUBJECTS AND/OR TO SOCIETY

The results of these studies will determine the optimal stimulus (frequency and amplitude) to be used in a whole body vibration stimulus and their application will result in the help development of a dynamic whole body vibration skeletal muscle strength training protocol. Subjects will also become familiarized with a new type of resistance training.

#### PAYMENT FOR PARTICIPATION

You will not receive payment for participation in this study.

#### CONFIDENTIALITY

Any information that is obtained in connection with this study that can identify you will remain confidential and will be disclosed only with your permission.

Data will be collapsed before results are printed. All subjects will be assigned an arbitrary number to ensure anonymity. Data will be stored for one year in a password protected file and then disposed of. Raw data will not be released to any other parties.

#### PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may also refuse to answer any questions you feel are inappropriate and still remain in the study. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

#### FEEDBACK OF THE RESULTS OF THIS STUDY TO THE SUBJECTS

Upon completion of the research project, the results will be available on the University of Windsor Research Ethics Board website: [www.uwindsor.ca/reb](http://www.uwindsor.ca/reb) under the section of Study Results by May 1st, 2006. I also plan to publish this study in a reputable academic journal upon the completion of the research as well as in a written thesis.

#### SUBSEQUENT USE OF DATA

This data will be used in subsequent studies.

Do you give consent for the subsequent use of the data from this study?

☐ Yes

☐ No

#### RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. If you have questions regarding your rights as a research subject, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; telephone: 519-253-3000, ext. 3916; e-mail: [lbunn@uwindsor.ca](mailto:lbunn@uwindsor.ca).

#### SIGNATURE OF RESEARCH SUBJECT/LEGAL REPRESENTATIVE

I understand the information provided for the study *The Effect of Whole Body Vibration on Muscular Activation* as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

\_\_\_\_\_  
Name of Subject

\_\_\_\_\_  
Signature of Subject

\_\_\_\_\_  
Date

#### SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

\_\_\_\_\_  
Signature of Investigator

\_\_\_\_\_  
Date



## LETTER OF INFORMATION FOR CONENT TO PARTICIPATE IN RESEARCH

Title of Study: **The Effect of Whole Body Vibration on Muscular Activation**

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Upon completion of the research project, the results will be available on the University of Windsor Research Ethics Board website: [www.uwindsor.ca/reb](http://www.uwindsor.ca/reb) under the section of Study Results by May 1st, 2006. I also plan to publish this study in a reputable academic journal upon the completion of the research as well as in a written thesis.

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This data will be used in subsequent studies.

Do you give consent for the subsequent use of the data from this study?

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☐ No

#### RIGHTS OF RESEARCH SUBJECTS

You may withdraw your consent at any time and discontinue participation without penalty. If you have questions regarding your rights as a research subject, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; telephone: 519-253-3000, ext. 3916; e-mail: [lbunn@uwindsor.ca](mailto:lbunn@uwindsor.ca).

#### SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

\_\_\_\_\_  
Signature of Investigator

\_\_\_\_\_  
Date



## VITA AUCTORIS

Name: Tom Hazell

Date of Birth: August 25, 1980

Place of Birth: Hamilton, Ontario, Canada

Education: Ontario Secondary School Diploma  
St. Mary's High School  
Hamilton, Ontario, Canada  
1994-1999

Honours Bachelor of Kinesiology  
McMaster University  
Hamilton, Ontario, Canada  
1999-2004

Master of Human Kinetics  
Faculty of Human Kinetics  
Department of Kinesiology  
University of Windsor  
Windsor, Ontario, Canada  
2004-2006